

SECTION 15755 SCRUBBED EXHAUST SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including Division 1, General and Supplementary Conditions apply to this Section.

1.2 SUMMARY

- A. This Section specifies the requirements to furnish and commission the scrubbed exhaust system. The scrubber system shall be furnished as a single packed bed system, complete with the following:
1. Sump for retaining a minimum of one and one half times the gallonage of solution required by the recirculation system.
 2. Packed section, including packing support.
 3. Head section, including internal liquid distributor laterals with external flanged liquid inlet connection, entrainment separator and separator support.
 4. Containment pan with removable covers.
 5. Chemical feed system for pH control or biocide addition including double contained tank, metering pump, and double contained piping from pump to scrubber.
 6. Liquid recirculation system with a 100% redundant recirculation pump.
 7. Exhaust Fan (two each connected in parallel, one on-line, one stand-by).
 8. Instrumentation, control systems, and local control panels.
 9. Equipment steel base suitable for flat equipment installation on a sloping roof.
- B. Contractor shall furnish complete scrubbed exhaust systems including:
1. FRP or polypropylene scrubber with packing, spray headers, and mist eliminator with transition pieces to match ductwork.
 2. Two FRP or polypropylene exhaust fans with vibration isolation as required.
 3. Instrumentation, controls, and local control panels.
 4. FRP or polypropylene containment pan.
 5. Preassembled recirculation system (pumps, piping, valves, spray headers, etc.), complete with interconnecting piping and power as required.
 6. Lifting and hold-down lugs.
 7. Interconnecting ductwork between scrubbers and fans including scrubber dampers inlet isolation.
 8. All services (power, etc.) are to be brought to single point connections on the units.
 9. Independent performance testing from Owner approved contractor list.
- C. Items supplied by Mechanical Contractor, Construction Manager, or Owner:
1. Process ductwork to scrubber inlet.
 2. Off loading, rigging, and setting.
 3. Anchor bolts, protective felt pad, and grouting for base plates.
 4. All connecting ductwork to scrubber inlet and from exhaust fan discharge to stack.
 5. Chemicals and makeup water supply.
 6. Electrical power.
 7. Wiring to the sitewide Facility Control System (FMCS).
- D. Related Sections include the following:
1. Section 15055 - Motors

2. Section 15842 - Centrifugal Process Exhaust Fans
3. Section 15884894 – Ductwork (Teflon coated stainless steel provided).
4. Section 15960 – Laboratory Airflow Control System.
5. Section 16050 – Basic Materials and Methods.

- E. In the event of conflict regarding scrubbed exhaust system requirements between this Section and any other section, the provisions of this Section shall govern.

1.3 REFERENCES

- A. The scrubbers shall be designed and fabricated to comply with all applicable national codes and standards and those local codes and standards indicated herein.
- B. American Society for Testing and Materials (ASTM).
1. ASTM C582, 1995 – Standard Specification for Contact-Molded Reinforced thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment.
 2. ASTM D2563, 1994 – Standard Practice for Classifying Visual Defects in Parts Molded from Reinforced Plastics.
 3. ASTM D2583, 1995 – Standard Test Method for Indentation Hardness of Rigid Plastics by means of Barcol Impressor.
 4. ASTM D3418, 1997 – Standard Test Method for Transition of Polymers by Thermal Analysis.
 5. ASTM D4167, 1997 – Standard Specification for Fiber-Reinforced Plastic Fans and Blowers.
 6. ASTM E84, 1998 – Standard Test Method for Surface Burning Characteristics of Building Materials.
- C. American Society of Mechanical Engineers (ASME) / American National Standards Institute (ANSI)
1. ASME/ANSI RTP-1, 1995 – Reinforced Thermoset Plastic Corrosion Resistant Equipment.
- D. National Electrical Manufacturers Association (NEMA)
1. NEMA Mg-1, 1987 – Motors and Generators.

1.4 SUBMITTALS

- A. Provide the following in addition to the standard requirements. Provide 10 copies.
1. With Bid:
 - a. A list of five successfully operating installations similar in capacity, application, and equipment type within the continental United States. Minimum service time on these installations shall be three years. Include name and telephone number of the plant engineer in charge of operating these units.
 - b. Materials of construction of scrubber body, packing, packing supports if used, mist eliminator, mist eliminator support, piping, pumps, distributor, and nozzles. The resin blend, promoter/catalyst/accelerator, reinforcement and surfacing veil, and any additives in each layer in the scrubber body shall be listed, as well as the flame spread rating.
 - c. Type, size, and sample of packing to be used.
 - d. Superficial cross-sectional area and depth of packed bed.
 - e. Complete catalog information on accessories including:
 - 1) pH and conductivity transmitters.
 - 2) Differential pressure and pressure transmitters
 - 3) Recirculation system pumps.
 - 4) Level and flow transmitters.
 - 5) Valves (manual, solenoid, and pneumatic).
 - 6) Differential pressure switches.

- 7) Gauges.
 - 8) Rotameters.
 - 9) Miscellaneous controls, materials, and components.
 - f. Unit costs of labor and expenses for additional field support.
 - g. Dimensioned system plan drawing for the systems with a typical section. Plan drawing shall indicate maintenance access areas, location of pumps, controls, connections to scrubber, etc. as required to indicate system operability and maintainability within the specified space.
 - h. Detailed description of scrubber fabrication method, and field assembly requirements (including a list of components which will be shipped loose).
 - i. Detailed description of the inspection and pretesting, and in-field testing procedures and criteria.
- B. Provide the following, in addition to the standard requirements within four weeks of purchase order acceptance.
1. Corrected or supplemental technical data to the information furnished with the bid.
 2. Recommended operating conditions including an explanation if different from those listed in this Specification.
 3. Overall and detailed scrubber system drawings, including locations of all external connections.
 4. Actual utility requirements.
 5. A written description of how the scrubber vessel will be protected in shipment and assembled in place so it does not leak in service if it must be supplied segmented.
 6. A plan for operational testing the scrubber after the system installation to verify conformance with requirements.
 7. Control wiring diagrams and control panel layout.
 8. All instrumentation, component, and material cutsheets.
 9. Structural design calculations for the scrubber anchors, packing support, fan and pump support. Structural design calculations shall be signed by a State of Tennessee registered structural engineer.
 10. Scrubber operating characteristics to include the packed bed superficial air velocity, gas side pressure drop across the scrubber and mist eliminator (measured from inlet duct transition to outlet duct transition), recirculation flow rate, operating pH, internal hydraulic calculations, absorption calculations, guaranteed and expected outlet loading for compounds listed at the operating pH, mist eliminator efficiency, and effect of pH on the removal efficiency.
 11. Scrubber performance calculations signed by a registered professional engineer.
 12. Projected utility consumption, including makeup water, blowdown, power, etc.
 13. Cutsheet on nozzles, number of nozzles, arrangement, and pressure drop calculations across a typical nozzle header.
 14. Details showing packing support construction.
 15. Panel face layout.
 16. Equipment steel base installation details.
- C. Required prior to Final Payment:
1. Operating and Maintenance Manuals. (10 copies)
 2. Operational Acceptance and Performance Tests.
 3. As-built fabrication drawings.

1.5 QUALITY ASSURANCE (in progress)

1.6 SCHEDULING

- A. Notify Construction Manager prior to the actual fabrication start date. The CM shall have the option to inspect prior to, during, and upon completion of fabrication and installation and witness tests and inspections.

1.7 COORDINATION

- A. The scrubbers, fans, and liquid recirculation system shall be coordinated with the Owner, Construction Manager, Engineer, and subcontractors to ensure the installed performance as specified in the attached Data Sheets.

1.8 DESIGN CRITERIA

- A. The scrubber system shall be designed to continuously meet the outlet loading requirements specified herein.
- B. Liquid makeup shall be industrial city water (nonpotable city water).

1.9 WARRANTY

- A. In addition to the general guarantee specified in the Contract, the Contractor shall guarantee the following:
 - 1. The system shall process the quantities and types of materials specified on the Data Sheets at the inlet temperatures and in accordance with all requirements as set forth in this Specification and the Data Sheets.
 - 2. Effluent gases from the system shall meet all local air pollution requirements as specified on the scrubber data sheet. Stack emissions performance guarantees shall be stated by the Manufacturer.
- B. Manufacturer shall provide the standard form of written guarantee and warranty covering defects in materials and workmanship for the equipment. Said guarantee and warranty shall be for a period of 1 year from the date of final acceptance of the equipment by the Owner. Manufacturer shall provide price for an additional 1 year warranty.
- C. The warranty shall cover the construction, materials, parts, labor, operation, and contaminant removal efficiency.
- D. All material or equipment found to be defective within the aforementioned period shall be replaced or repaired to like-new condition at no cost to the Owner.
- E. Manufacturer shall specify in the proposal the limits of warranty coverage (parts and labor) for major components of the package. Manufacturer shall specify the necessary customer maintenance to keep the applicable warranty in effect.
- F. Painted surfaces shall be guaranteed for 1 year against fading, chipping, and rusting.
- G. Metal surfaces and fasteners shall be guaranteed for 1 year against rusting.
- H. Provide written warranty and guarantee, five copies to the Owner at the time of submittal.
- I. Date of acceptance shall be defined as the date that the Owner assumes operation of the unit. Contractor must receive written letter of acceptance to begin warranty period.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Resin:
1. The following resins are acceptable when they contain 5 percent antimony trioxide:
 - a. Derakane 510A and 510N.
 - b. Atlac 711-05A5.
 - c. Hetron FR 992.
- B. Reinforcement:
1. Type E glass as chopped strand felted mat and woven roving and styrene soluble binder.
 2. Minimum 10- to 20-mil surfacing veil as Nexus or Dynel.
 3. All reinforcement must be clean, dry, and unused.
- C. Catalysts/Promoters/Accelerators:
1. The following are acceptable:
 - a. Cobalt Napthenate.
 - b. Dimethyl Aniline.
 - c. Methyl Ethyl Ketone.
 - d. Benzoyl Peroxide.
 2. Selection of specific catalyst/promoters/accelerators will be suitable to the resin and fabricator's equipment and formulated as recommended by the resin Contractor.
- D. Additives:
1. The following additives are acceptable:
 - a. Antimony trioxide for fire retardance to be as supplied by M&T Chemical, Inc.
 - b. UV absorber to be Cyanasorb UV5411.
 - c. Other additives, such as bulking or thixotropic agents, are not acceptable.
- E. All materials (in exhaust stream, liquid recirculation, etc.) shall be resistant to corrosion and UV degradation based on the design and anticipated upset conditions.

2.2 FABRICATION

- A. Scrubber:
1. Each scrubber shall be of horizontal packed bed design suitable for induced draft operation.
 2. Each packed bed shall be designed with a maximum pressure drop of 2.0 inch WC and a maximum superficial velocity of 500-~~700~~ fpm.
 3. Each scrubber shall include an impingement type mist eliminator prior to discharge from the scrubber.
 4. A liquid reservoir shall be provided as an integral part of each scrubber capable of retaining the volume of liquid that drains from the packed section for feed to the recirculation pumps.
 5. Each scrubber sump shall be designed to enable drainage of all liquid for periodic maintenance. Each scrubber shall have a flat bottom exterior base, with an interior sump bottom that slopes one percent toward the sump drain. The sump drain shall be a valved bottom drain with provision for local and remote operation. The sump drain shall penetrate through the containment pan with the valve outside the containment. The penetration shall be leaktight.
 6. Scrubber Construction Materials:
 - a. Fiberglass-reinforced plastic (FRP) with a Class I flame spread rating of 25 or less when tested per ASTM E84, Steiver Tunnel Test Laminate shall contain no fillers,

- except as required to obtain fire retardance, or color, and in no case shall exceed 5 percent by weight.
- b. Polypropylene shall be capable of withstanding the contaminants stated in the data sheet. The polypropylene shall be assembled using the most current state-of-the-art fabrication techniques using fusion, extrusion welding, and seamless corners wherever possible.
7. Each scrubber shall be designed and constructed to withstand a maximum vacuum of 14 inches WC. The scrubber bottom shall be reinforced and have a minimum thickness of 1 inch. The scrubber walls shall not be less than ½-inch thick.
 8. Side mounted rectangular access doors of clear plexiglass gasketed and bolted to ports 1 foot-6 inches high inside dimension by 2 feet wide inside dimension for access and viewing shall be provided on each scrubber. The access and viewing ports shall be located at the inlet and outlet and above the highest liquid level of the sump.
 9. All external connections shall be constructed integral with the scrubber with flanged pipe connections to be drilled in the field for connection to external piping following installation assembly.
 10. No bulkhead type fittings shall be used below the top of the liquid overflow external connection.
 11. Provide integral with the scrubber all internal and external supports required to bear the loads associated with the packing support, the liquid distributor, and the entrainment separator.
 12. The top of each scrubber shall be designed for a maximum load of 250-pounds per ASME/ANSI RTP-1.
 13. All pipe integral with the scrubber for external connections shall be Schedule 80 PVC or CPVC.
 14. Provide a common FRP or polypropylene containment pan with removal covers around each scrubber system. This containment pan shall be 12 inches deep and extend a sufficient distance out from each scrubber to collect any leaks. Open grating shall be substituted for covers where there is a potential for leaks (e.g., under spray header piping, etc.).
- B. Packing and Support:
1. Packing material shall be a standard Contractor's product of geometric shapes designed for turbulent mixing of liquid and gas as manufactured by Jaeger, Tri-Pack, Tellerette, or Lanpac.
 2. Packing shall be supported in the airstream and above the sump bottom. The packing support shall be designed and constructed to perform based on the wet clean packing loading at startup conditions, as well as during worst case anticipated operation with an additional safety factor. The recommended safety factor shall be 5 times the wet clean packing loading at the allowable material stresses.
 3. Packing shall be of a plastic material and suitable for a minimum of 10 years use at the design conditions without deterioration and corrosive attack.
 4. The initial supply of packing material shall be sufficient to maintain the specified performance characteristics and depth of packing after 3 months of continuous operation during which the packing material may settle and compact.
- C. Liquid Distributor:
1. Liquid shall be distributed within the scrubber from a system of pipe laterals and nozzles designed to evenly distribute the recirculating water across the entire packing surface.
 2. Liquid distributor nozzles shall be selected to completely wet the top of the packing. Each row of nozzles shall have a diaphragm valve for balancing and isolation.
 3. Each liquid header shall be designed to minimize the pressure drop across the header and provide the same pressure within ±10 percent at each nozzle.
 4. Any scrubber internal liquid distributor lateral with nozzles shall be removable for maintenance without entering the scrubber or requiring removal of any other internal or external piping.

5. Internal liquid distributor laterals shall include unions or flanged connections to allow dismantling of pipe in sections not to exceed 5 feet.
 6. Common inlet liquid header external to the scrubber shall be located above liquid inlet distributor laterals so as not to interfere with upper access and viewing port.
 7. Gaskets and bolts shall be provided for connecting the common header to the liquid distributor laterals during scrubber assembly. Bolt sets shall be 316 stainless steel; gaskets shall be EPDM or Viton.
 8. All piping shall be Schedule 80 PVC or CPVC.
- D. Entrainment Separator:
1. Scrubber shall have an impingement type entrainment separator of chevron design suitable for horizontal flow and located at the outlet section of the scrubber prior to gas discharge.
 2. Entrainment separator shall be capable of removing in excess of 99 percent of the entrained droplets on a total weight basis.
 3. Water spray system shall be provided to wash the gas inlet face of the entrainment separator. The water spray system shall be provided with a ball valve, solenoid piloted pneumatic valve, and a timer to control the valve.
- E. Liquid Recirculation System:
1. The recirculation system may be integral and self-contained with the scrubber or remote from the scrubbers with all interconnecting piping and power provided. The system shall be designed to pump the required scrubbing solution from the sump to the distributor nozzles, as determined by the surface area of the packing material and the scrubbing efficiency.
 2. The system shall consist of recirculation pumps (one pump plus one 100 percent back-up for each scrubber), piping, valves, instrumentation, and controls. Pumps shall be of adequate size to meet the flow requirements of the scrubber and shall be constructed of acid and caustic resistant materials compatible with the solution being pumped. The pump shall be designed to operate within the optimum range of the slope of the pump characteristic curve with an impeller in the midrange of the available sizes for the particular pump. The pumps shall be designed to resist damage from debris. Pump motors shall be high efficiency, chemical duty type with TEFC enclosures and in conformance with the requirements of Section 15050. Motor starters shall be furnished by scrubber Contractor. Pumps shall be manufactured by Fybroc, Ingersol Dresser Rand, Vanton or equivalent.
 3. The recirculation system shall have line size strainer(s), located on the pump inlet to prevent plugging of the nozzles.
 4. All piping, valves, and nozzles shall be Schedule 80 PVC or CPVC. Valves shall be Tru-Union ball or diaphragm up to 2-1/2-inch, and lug style butterfly type for sizes 3 inches and larger. Butterfly valves shall be Grinnell 8000 Series, Bray 31 Series, DeZurik 632 Series, or Fisher Control Series 8550 or 9500.

F. Equipment Isolation:

1. For equipment located on the roof of the cleanroom or in EVA sensitive areas (EVA= Emissions, Vibrations and Acoustics), provisions need to be made to prevent the transmission of mechanical vibrations from the equipment to the support structure. When necessary, an effective structural isolation break (SIB) shall be provided.
2. Structural Isolation Breaks shall be provide at specified locations to reduce coupling between vibration-sensitive areas and areas containing vibration-producing equipment, such as fans and pumps.
3. Install isolators for fans, pumps and other such equipment associated with the scrubber package. Unless otherwise allowed by the Vibration Consultant, no equipment of more than three horsepower is to be attached to the structure without suitable vibration isolation. Where piping connects to such equipment, provide flexible connectors

SCRUBBED EXHAUST SYSTEM
KNIGHT/JACOBS JOINT VENTURE

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4. Passive mechanical equipment such as heat exchangers, storage tanks, and expansion tanks do not require vibration isolation from the building structure.
5. All rotating equipment shall operate at speeds less than 80% of their true critical speed.
6. Pumps, fans, and other rotating equipment shall be tested after installation and under operating conditions. Vertical and horizontal vibration shall not be greater than the levels indicated. The vibration shall be measured on the equipment bearing caps when the equipment is mounted on its vibration isolation mounts. If the equipment has an inertia base, the allowable vibration level is reduced by the ratio of the equipment weight alone to the equipment weight plus inertia base weight. A balance report will be provided for each item of equipment.

Equipment Speed	Vibration Displacement (MILS) peak-to-peak
Under 600 rpm	4
600 to 1000 rpm	3
1000 to 2000 rpm	2
Over 2000 rpm	1

7. All vibration-isolation mounts shall be supplied by one of the following approved manufacturer's. Exception to this clause may be permitted in the case of internally isolated equipment with the explicit approval of the Contractor.
 - a. Kinetics Noise and Control, Inc., Dublin, Ohio.
 - b. Mason Industries, Inc., Hollis, New York.
 - c. Amber/Boot Company, Houston, Texas.

2.3 ACCEPTABLE MANUFACTURERS

- A. Harrington.
- B. Trimer.
- C. Ceilcote.
- D. Beverly Pacific.

2.4 ACCESSORIES

- A. Provide a continuous corrosion resistant seismic plate or hold-down lugs for attachment to the roof support structure. ~~concrete pad.~~
- B. Sight Glass: Provide a sight tube on the scrubber sump with tru-union ball valves at the inlet and outlet. The sight glass shall be provided with self-closing check valves such as manufactured by Ernst Model A-2PVC automatic to prevent drainage of the sump in the event of accidental breakage of the sight glass. The sight glass shall be located and installed to minimize the possibility of accidental breakage. The sight glass shall also be appropriately protected from such damage with a frame or shield such as Ernst Gage Glass Protectors Figures 31 or 727 as required based on placement.
- C. Nameplates: Permanently attached corrosion resistant equipment labels shall be supplied with each equipment unit and components (including pumps and instrumentation). Equipment labels shall include:
 1. Equipment name.
 2. Equipment identification tag number.

3. Design capacity, cfm, Static Pressure Loss (WC), volume of packing (ft³).
4. Name of manufacturer, model, and serial number.
5. Year built.
6. Purchase order number.

2.5 AIR SIDE COMPONENT FABRICATION

A. FRP Centrifugal Exhaust Fans

1. General requirements: Provide backward inclined, single width, single inlet with an internal inspection access door, Neoprene shaft seals to prevent leakage of fumes, flanged inlet and outlet connections, and 316L stainless steel fan shaft, bolts, nuts, washers, and flexible connectors. Fan wheel shall be fiberglass coated steel.
2. Fiberglass reinforced polyester material:
 - a. FRP Laminate: Consists of an inner surface layer, an intermediate layer and a structural layer.
 - b. Inner surface exposed to the chemical environment: Consists of a resin rich chemical resistant glass surface mat provided in 2 piles to ensure a corrosion resistant layer of 0.020" - 0.030" thick. The first surfacing mat ply shall be a synthetic surface veil such as Nexus. Provide a glass surface mat adjacent to the interior layer of laminate to improve the interlaminar bond and to produce an air-free laminate. The inner surface shall be free of cracks and crazing, with a smooth finish with an average of not more than 2 pits 0.015" deep and wide per square foot, and covered with sufficient resin to avoid exposure or random glass fibers.
 - c. Intermediate inner layer: Consists of resin reinforced with noncontinuous glass fiber strands, having fiber lengths from 0.5" to 2.0" applied by using 1-1/2 oz. chopped strand mat or chopped glass roving. Well roll each ply of chopped mat or roving prior to succeeding application. Provide a combined inner surface intermediate inner layer thickness of no less than 0.10" and glass contact of the combined inner surface and the intermediate layer 27% ±3% by weight.
 - d. Structural layer: Consists of chopped strand mat or equivalent weight of chopped roving and additional alternating plies of woven roving to achieve the specified wall thickness.
 - e. Exterior surface: Smooth, with no exposed fibers provided with a high quality fire retardant intumescent coating.
 - f. Resin: Vapor and liquid phase chemical resistant, high tensile elongation and maximum crack and craze resistance of the finish surface. Add a maximum of 8% antimony pentoxide to the resin to provide ASTM E84, Class 1 fire retardancy.
 - g. Acceptable resins are as follows:
 - 1) Ashland Chemical Hetron FR992.
 - 2) Dow Chemical Derakane 510-A vinyl ester.
 - 3) Koppers Atlas 711-05.
 - 4) Dion 6695FR brominated bisphenol-A polyester.
3. Acceptable Fan Manufacturers are as follows:
 - a. Harrington
 - a-b. New York Blower.
 - b-c. Chicago Blower.
 - c-d. Trimer Corp. (New York Blower Wheel)
 - d-e. Approved Equal (Approval must be obtained prior to bid submittal for consideration).

~~B. Fiberglass reinforced plastic ductwork.~~

1. ~~Refer to reference Specification 15880, Section 2.9: FRP Ductwork.~~

2.6 CONTROLS

- A. Local Control Panels: Local NEMA 4X (nonmetallic) or epoxy coated NEMA 4 panels shall be provided with each scrubber for all instrumentation and controls. The panels shall be fabricated in accordance with Division 15, Electrical Components for Packaged Equipment. All wires shall be identified with sleeve type wire markers at each end. Wraparound or hand lettered wire markers shall not be used. The panel shall consist of two compartments with a grounded separation barrier. One compartment shall house all the instrumentation and controls as defined hereafter while the second compartment houses the power distribution system. The panel shall be provided with a thermal magnetic main circuit breaker with provisions for dead front (external) operation and lockable in the OPEN position. The main circuit breaker or fusible switch shall have short circuit rating of 100,000 amps rms symmetrical. The panel shall be provided with full voltage, nonreversing, circuit breaker type, combination magnetic motor starters for pump motors rated at 480 volts, 3-phase, 60 Hz, with short circuit rating of 100,000 amps rms symmetrical, and with 120 volt control power transformer. Motor starter shall be Allen-Bradley or Square D. The circuit breakers shall be externally operable. All wiring from each power and control panel to their respective drive motors, heaters, and/or control devices shall be installed at the factory.
- B. Variable Frequency Drives
1. Capacity control of scrubber system fans shall be through the use of variable frequency drives when specified in the data sheet. Drives will accept a pressure signal from the FMCS.
- C. Motors
1. Motors shall be in accordance with the requirements of Section 15050, Basic Materials and Methods, and Section 15055, motors 15173, ~~Electrical Components for Packaged Equipment.~~
 2. Motors shall be fully compatible with adjustable speed drives such that drive induced vibration does not exceed balance levels ~~specified in Section 15051, Basic Mechanical Requirements for Owner Purchased Equipment.~~
 3. Motors shall be capable of accepting pulse width modulation signal from adjustable frequency drives utilizing GTO, IGBT, or Darlington transistor technology. Motors shall be matched to the drives and shall not require derating to be used with drives.
- D. Instrumentation and Controls:
1. All instrumentation and controls shall be industrial grade components constructed of stainless steel or other corrosion resistant materials and provided with NEMA 4X housings or enclosures. Controllers shall be Allen-Bradley PLC based units. The sensing elements and transmitters shall be supplied as integral units with 4 to 20 maDC outputs that are rated to at least 0.5 percent accuracy. All transmitters shall be two-wire type. All devices that are not mounted in-line (i.e., controllers, readouts, timers, etc.) shall be mounted in the local control panel. All control air and sensor tubing (i.e., pressure sensors) shall be stainless steel with Swagelok connections and Nupro valves. All solenoid valves shall be constructed of 316 stainless steel and operate on 120V with a manual override. The solenoids shall be made by ASCO. Pressure and differential pressure transmitters and gauges shall have an accuracy of $\pm\frac{1}{2}$ percent. All instrumentation shall be selected to fall within 50 to 70 percent of the full scale during normal operation. The full scale value shall be selected based on worst case conditions (i.e., pump shutoff head, etc.).
 2. The signals that are to be transmitted to the FMCS from the scrubber control panels shall be by interruption of the transmitter loop such that the accuracy is maintained or by a retransmission signal which shall be at least 0.25 percent accurate when compared with the originating signal.
 - a. If the method of interrupting the 4 to 20 maDC loop is chosen, two terminals and a shield connection shall be identified for the FMCS tie-ins and a jumper inserted

- across them that will be deleted when the FMCS is connected. The transmitters and power supplies shall be capable of driving into an additional 250-ohm load of the FMCS above and beyond what is required by the scrubber control panel instruments.
- b. If the method of retransmission is chosen, two terminals and a shield connection shall be identified for the FMCS tie-ins and the 4 to 20 maDC signal shall be capable of driving the 250-ohm load of the FMCS.
 - c. All general alarm conditions shall be connected to a single contact point for output to the FCMS.
3. A differential pressure transmitter (loop powered) shall be mounted across the scrubber body to monitor the pressure drop across the scrubber packing. The indicator shall be located in the control panel and constructed of 316 stainless steel. The unit shall be as manufactured by Rosemount 1151DP Series or Foxboro 841 Series. The unit shall be piped appropriately to drain condensate from the sensing tubes. If the transmitter cannot be mounted accessible and maintain the proper draining of the sensing tubes, then differential pressure transmitters with remote seals shall be used. These shall be Contractor filled and provided as a complete assembly. The duct block valves shall be sized accordingly.
 4. Valved pressure gauges shall be provided at each recirculation pump outlet. The gauges shall be stainless steel Bourdon tube type with a minimum 2-1/2- inch dial face by Ashcroft 1279 Duragage Series, Plastomatic, or US Gauge. All gauges shall be provided with corrosion resistant gauge guards.
 5. A valved differential pressure switch shall be provided at the common discharge header of the recirculation pumps. The differential pressure switch shall activate an alarm when the pressure drops below the level required to maintain the required design performance.
 6. Rotameters shall be provided in each spray header lateral and in the make-up water piping. The rotameters shall be as manufactured by Fischer & Porter, Wallace & Tiernan, or George Fischer.
 7. A solenoid piloted pneumatic valve shall be provided in the blowdown line off the common pump discharge header. This valve shall be activated by pH and conductivity to blow down the recirculating water. The solenoid shall be normally closed (failed closed). The blowdown valve discharge rate should be less than the available make-up water rate.
 8. Makeup water to the sump shall be provided from two sources: a manual fill and auto fill. A manual fill source shall be provided with a manual isolation valve. The auto fill source shall be provided with a normally closed (fail closed) solenoid piloted pneumatic valve to be actuated by a low level signal from the scrubber unit controller.
 9. Sump level shall be monitored by a multi-level magnetic float switch tree or ultrasonic type transmitter. The transmitter shall be constructed of 316 stainless steel with indicator lights located in the control panel.
 10. A ball valve shall be provided at the inlet of the recirculation pumps for the addition of a biocide to the sump.
 11. In-line flow-through conductivity and pH probes shall be provided in the common pump discharge with an indicator mounted in the control panel. The transmitters shall have adjustable setpoints and 4 to 20 mA outputs to control chemical addition and recirculating water blowdown via the scrubber unit controller.
 12. A pressure switch shall be provided on the automatic makeup water source to provide an alarm input for low make-up water pressure to the scrubber unit.
 13. The recirculation pump motors shall be provided with power interrupt sensors to allow the standby pump to start when power is interrupted (i.e., motor failure) to the primary pump. An alarm shall be provided to indicate such conditions.
 14. All pressure switches, inline sensors, and gauges shall be provided with bypasses or isolation valves to allow periodic maintenance or replacement.
 15. The local unit control panel for each scrubber shall include the following:
 - a. Alarm (red light) indication of high or low differential pressure across the scrubber.
 - b. Alarm (red light) indication of high and low sump level.

- c. Analog indication of the pH and conductivity; visual (red light) indication of pH high and low, and conductivity high.
 - d. Alarm (red light) indication of low recirc pump pressure.
 - e. Audible indication of all alarm indications with RESET, ACKNOWLEDGE, and TEST buttons. The ACKNOWLEDGE button shall silence the audible alarm and maintain visual indication. The RESET button shall deactivate the alarm lights. The TEST button shall activate the visual and audible indicators.
 - f. Provide a HAND/OFF/AUTOMATIC handswitch for each recirculation water pump.
 - g. Provide indication at the panel that scrubber controller unit is On.
 - h. All indicating lights shall be LED type, push-to-test; green = RUN.
16. A separate terminal strip shall be provided and labeled to facilitate the connection of all controls to the Owner's FMCS.
17. The PLC system shall be supplied with a Modbus communications network connection for communication to the Owner's system.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Inspection:
- 1. Manufacturer will inspect all FRP components after fabrication and final cure per ASTM D2563 and ASME/ANSI RTP-1. Interior surfaces will be Acceptance Level II; exterior surfaces shall be Acceptance Level III.
 - 2. Manufacturer will also inspect all FRP components for adequate cure per ASTM D2583, ASME/ANSI RTP-1, and an Acetone Test as described below:
 - a. Saturate a clean, lint-free rag with commercial grade acetone.
 - b. Wipe the rag to wet a 6-inch diameter circle.
 - c. Allow wetted circle to dry for 5 to 10 minutes.
 - d. Touch the circle with the back of an index finger fingernail.
 - e. If the fingernail sticks to the surface, the cure is inadequate and additional curing (possibly at elevated temperature) or other approved remedial action is required.
 - f. Acetone test shall be done with the tank well ventilated.
 - 3. Compliance check for scrubber dimensions per Manufacturer drawings.
- B. Repair:
- 1. Unacceptable nonstructural defects will be repaired by grinding out the defect and reapplying the corrosion barrier (inner surface and interior layer). Structural integrity shall not be violated during these repairs.
 - 2. Structural defect repair procedures require prior review by the Construction Manager. Prior to repairing structural defects, manufacturer will notify Construction Manager in writing of the defect type, location, and size and describe the proposed repair procedure.
 - 3. Any repairs made shall maintain UL listing on panel.
- C. Prior to Shipment: Testing shall be performed as follows and as necessary to ensure safe and reliable operation:
- 1. Hydraulic Test: At a minimum shall include testing of the sump, containment pan, and piping as follows:
 - a. The scrubber sump shall be tested at a hydraulic head of 2 feet above the top of the overflow outlet for a minimum of 2 hours.
 - b. The containment pan shall be tested by filling with water and visually inspecting for leaks.
 - c. The piping shall be hydraulically tested at 110 percent of the maximum pump discharge head for a minimum of 4 hours.
 - 2. Pump Run Test: The proper operation and performance characteristics of each pump shall be verified.

3. Preassembly for Fit: The entire scrubber system shall be assembled to ensure proper fit, clearance, maintenance, access, etc. The number of pieces to be shipped shall be kept to a minimum and each piece shall be clearly labeled for assembly. Detailed, step-by-step assembly instructions and coordinated drawings shall be provided for the installers.
 4. Calibration: All instrumentation shall be calibrated and ranged for this specific application.
 5. Functional Controls Test: The functional controls test shall, at a minimum, include a continuity test of all wiring and loop testing of all control wiring.
- D. Owner's Representative may witness manufacturer's inspections. Manufacturer will notify Owner's Representative at least five working days prior to inspection.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. Manufacturer shall provide pre-assembled and pretested scrubber systems delivered to the site. The units shall include complete, detailed assembly and installation instructions and drawings specific to the units being furnished. Manufacturer preassembly shall minimize the amount of field installation required.
- B. Prior to plant startup and after field installation all scrubbers shall be inspected by the manufacturer for proper alignment, connection, function, and to verify compliance with the Drawings and Specifications. Manufacturer shall work with the project commissioning team to coordinate this activity. The manufacturer shall document the commissioning effort using the pre-approved project commissioning forms.

3.3 DEMONSTRATION

- A. The system performance shall be demonstrated by testing the units per 40 CFR 60 Appendix A or local authority approved Test Methods as specified by Owner. The testing shall be conducted by an Owner's approved firm following protocol specified by the Owner.
- B. If the performance tests demonstrate that any scrubber does not meet the removal efficiencies as required by the Scrubber Data Sheets for certain target compounds (to be selected by the Owner), the manufacturer shall be responsible to adjust or improve the scrubber (including all labor and material costs), in order to bring the scrubber(s) into compliance with these specifications. The manufacturer shall also be responsible for all costs associated with retesting the deficient scrubbers. If the scrubber operation or design cannot be made to meet the required removal efficiencies within a reasonable time after the testing date, the manufacturer shall replace the scrubbers with new units which will meet the specification requirements, or refund 110 percent of the costs of the scrubbers, including installation, removal, and transportation costs.

END OF SECTION 15755